NIRSPEC

UCLA Astrophysics Program **U.C. Berkeley** **W.M. Keck Observatory**

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NIRSPEC Cryomechanics Design Note 1.00
Image Rotator

Field rotation

NIRSPEC will be mounted on the Nasmyth focus at Keck. This has the advantage that the instrument will remain stationary. However the alt-az mount of Keck means that the field will rotate. Thus it is necessary to de-rotate the field with an image rotator. The rotator only needs to move half of the field rotation rate. The range of the rotator then should be about 180E. Allowing for some extra motion at the end of the range of motion means the full range of the rotator arm should be about 190E.

The basic equation for the field rotation rate is

$$\frac{dp}{dt} = \Omega \cos A \frac{\cos \varphi}{\sin z}$$

where : dp/dt = field rotation rate
Ω_= sidereal rate = $7.29x10^{-5}$ rad/sec
φ_= latitude
A = azimuth
z = zenith angle

Keck blind spot is 0.7E by 0.44E centered at zenith.
Slit is 30" long and slit width is 0.4".
Keck latitude is 19.833E.

Rotator resolution

The field rotation rate changes with position on the sky. Field points at the end of the slit will rotate fastest. The requirement for the rotator is that the smear at the end of the slit should not be more than 10% of a resolution element (0.02" for 0.2" pixel). This will determine the maximum step size. Since we only have to move the rotator half as much as the sky:

max. step size = max. smear/2 = (0.02"/15")/2 = 0.0382E

The fastest field rotation for any part of the sky will be used to determine the maximum motor speed needed for the desired resolution. The fastest field rotation will occur at A = 0E and z = 0.22E. (The edge of the Keck blind spot closest to zenith.)

$(dp/dt)_{max}$ = 1.024E/sec

from the above equation for field rotation. The maximum motor speed required anywhere on the sky is determined by the maximum step size and the maximum field rotation.

(max motor speed for max step size) = 0.5* $(dp/dt)_{max}$ /max step size
= (0.5*1.024E/sec)/(0.0382E/step)
= 13.4 steps/sec

Motor speeds for different regions of the sky:
Motor speed range: 0-13.4 steps/sec
A typical value is 0.07 steps/sec = one step every 14.3 sec
The fraction of sky with speed > 1 step/sec # 1.1%

Then the gear ratio for the maximum step size is
GR = (0.9E /step)/(0.0382E/step) = 23.6
We may want to use a larger gear ratio to make the motion finer. That way if the motor is powered down and loses a step it won’t matter.

Thermal load

Power produced by motor:
(for Gemini, motor = API M162-03, driver = P42)
for continuous low power I = 0.455 Amps
R = 2.53 Ohms
P = 0.52 Watts

Resonances

We may want to increase the minimum gear ratio to get finer resolution. In that case we need to worry about resonances. Motors in Gemini are run at thousands of steps per second and resonance is not a concern. Primary resonance occurs in the range 0.5 - 1 rev/sec or 200 - 400 steps/sec. The fastest we need is 13.4 steps/sec but if we increase the gear ratio we will need to worry about this. Also secondary resonances may be a concern.

Mechanical Design

Two mechanical designs have been suggested for the image rotator assembly. One uses four small bearings and the other uses two large bearings. Both involve mounting the two flat mirrors in a cylindrical drum. This would also support the arm which holds the collimating mirror. The drum would have a hole cut in it to allow the beam to pass to the collimator and back. In the small bearing design the drum sits on the four bearings which are mounted in a vertical support plate. Gravity would help to keep the drum in contact with the bearings since it always points downwards. Also, bearings could be used above the drum to further confine it. The design is shown in Figure 1. The second design uses large bearings through which the beam would pass. The bearings could be press fit into vertical support plates. A steel flange could fit into the inner race (made of steel) and bolt onto the aluminum drum. This design has not yet been drawn in 3-D but should be shortly. An anti-backlash worm and worm gear will be used. The gear could be clamped onto one end of the drum.

Tilt stability

Any tilt in the rotator assembly will cause a shift of the image at the slit plane. If the shift is large, the image may be occulted by the slit. A goal for the stability of the assembly is that the shift should not be more than 10% of the slit. For a 200 Fm slit the allowable shift is 20 Fm.

$$\Delta x = \Delta\theta\, F$$
$$= \Delta\theta\, f/\#\, d_{pup}$$

$$\Delta\theta = 2\,\delta\theta$$
$$= 4\,\frac{\Delta r}{d_b}$$

$$\Delta x = 4\,\frac{\Delta r}{d_b}\, f/\#\, d_{pup}$$

where: Δx = shift at the slit
$\Delta\theta$_=_tilt of output beam from rotator assembly
F = focal length of the doublet
f/# = f/# of doublet = 10
d_{pup} = diameter of pupil = 26.6 mm_
$\delta\theta$_=_tilt of the rotator
Δr = radial runout of the bearing
d_b = distance between the bearings . 160 mm

Notice that the angular shift of the output beam is twice the angular shift of the rotator assembly. This is because of the reflections that the beam goes through. For Δx = 20 Fm and d_b = 160 mm, Δr = 3.0 Fm. These figures are for the latest values I have for the optical design. The distance between bearings used may be slightly larger than is necessary to mount the mirrors. This is to make the assemble less sensitive to the radial play in the bearings. The larger the distance between them, the less will be the effect of the radial play.

Double row cylindrical roller bearings with a tapered bore are available from SKF with the required tolerance. The exact radial runout depends on the size of the bearings. For the range 60 - 80 mm the radial runout is 2 Fm. For 80 - 120 mm the radial runout is 3 Fm. The diameter of the beam at the rotator is about 70 mm. Gravity will also be pressing the bearings downward contributing to the stability of the assembly. These bearings cost $378 per set and delivery would be in 3 - 4 days.